TOPICS

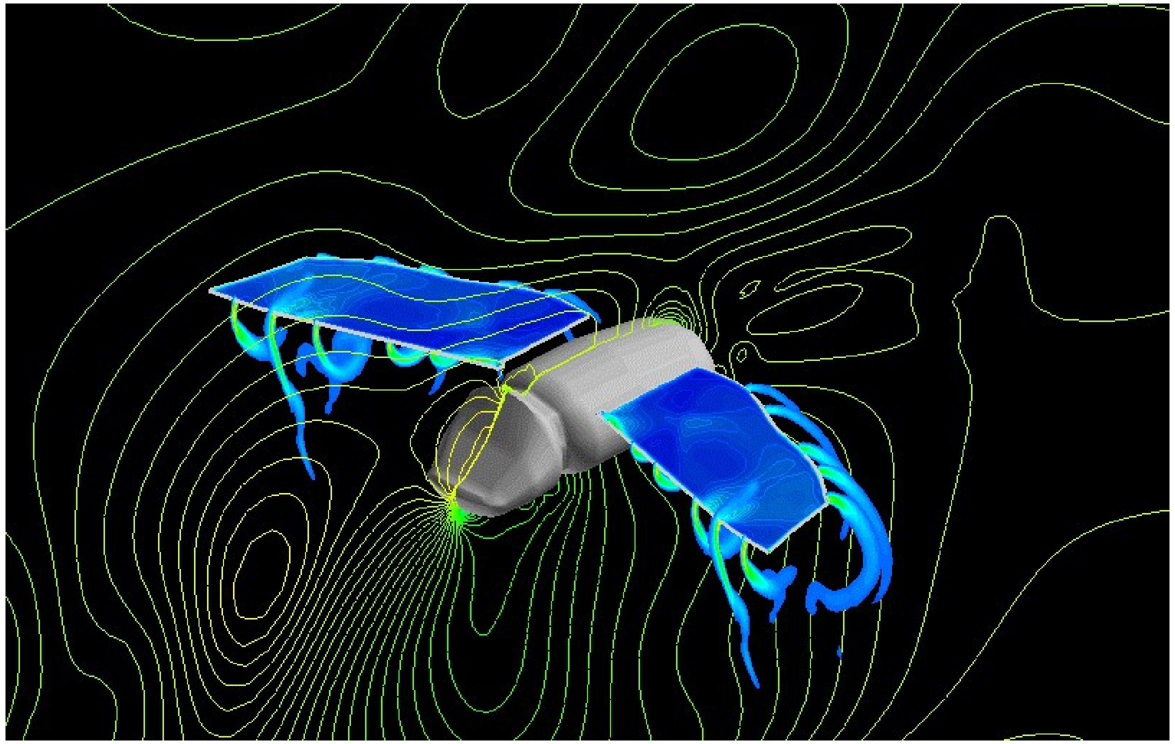
Custom Dev

Membrane FSI Application

Development

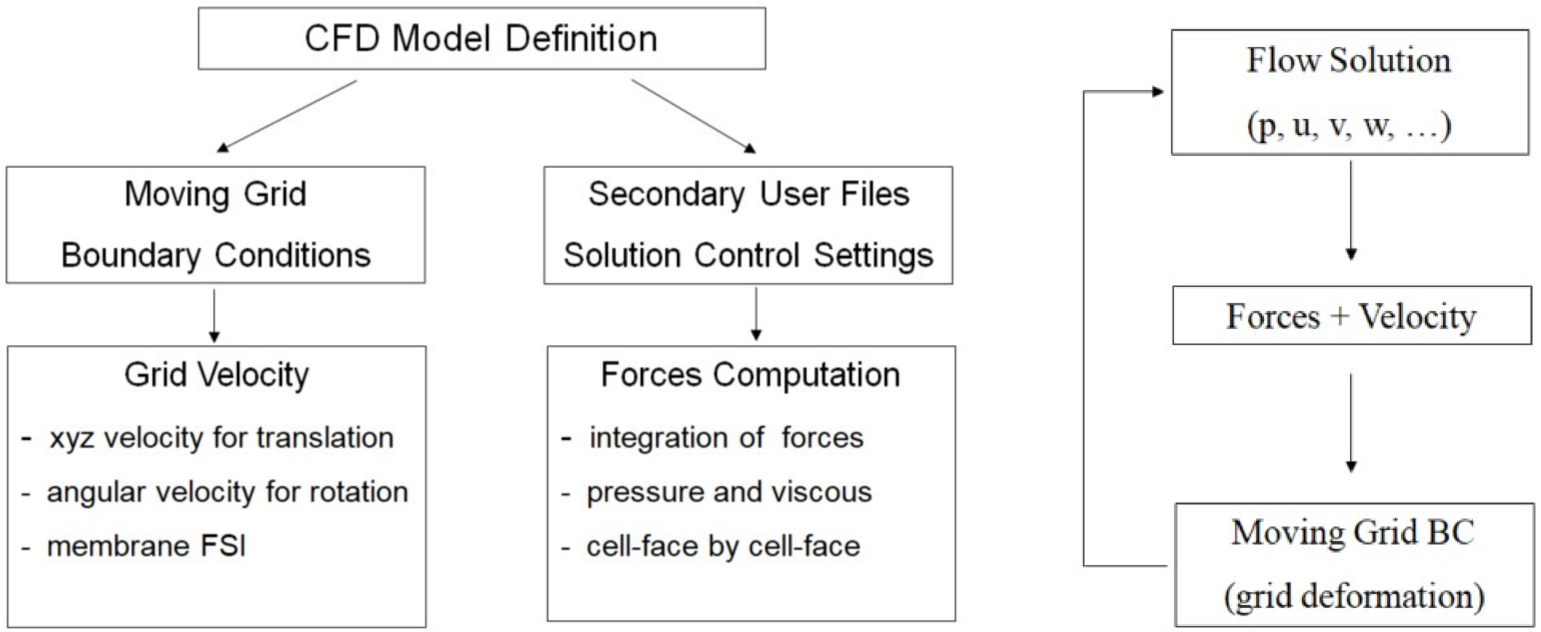
Customized solutions are required for many types of engineering applications. Most of the time, this requires a modification to the NS flow solver in order to add some new physics or simulation capability.

Fluid-Structure Interaction (FSI)



Development Approach

Fluid-Structure Interaction (FSI) - Flapping Wing



Membrane FSI Application

Development Approach

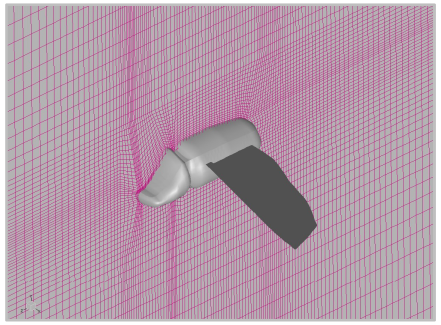
Moving Body Treatment

When the computational grid moves as a function of time, the grid velocity is included in discretizing the governing differential equations. The grid motion affects the convective fluxes of mass, momentum, energy, and other scalar dependent variables.

In integral form, the continuity and the generalized transport equations can be written as follows:

Continuity Equation

$$\frac{d}{dt}\int_V \rho dV + \int_A \rho\left(\vec{V}-\vec{V}_g\right)dA = 0$$



General Transport Equation

$$\frac{d}{dt}\int_V \rho\phi dV + \int_A \rho\phi\left(\vec{V}-\vec{V}_g\right)dA = \int_A \Gamma\nabla\phi dA + \int_V S dV$$

where V is an arbitrary moving volume, A is the surface of V, is any scalar quantity, and S are the diffusive flux and source terms for the corresponding variable. The mass and other convective fluxes across the cell faces are calculated according to the local fluid flow conditions and grid velocity. The cell volume, face area, and face direction cosines are recalculated at every time step.

TOPICS

Membrane FSI Application

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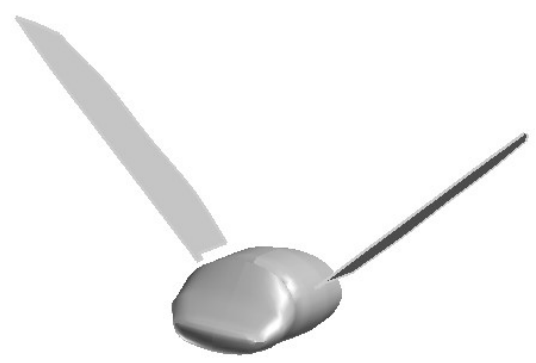
Development Approach

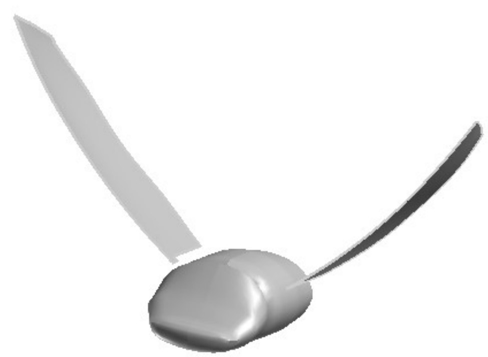
Prescribed Wing Bending

The primary wing flapping motion is **rotation** approximately about the beetle hinge centerline. Bending (or a curvature from beetle hinge location to wing tip) is observed in the beetle wing motion. This is modeled with a scaling function applied as a function of distance to wing tip.

Flat Wing



Prescribed Bending Wing



TOPICS

Membrane FSI Application

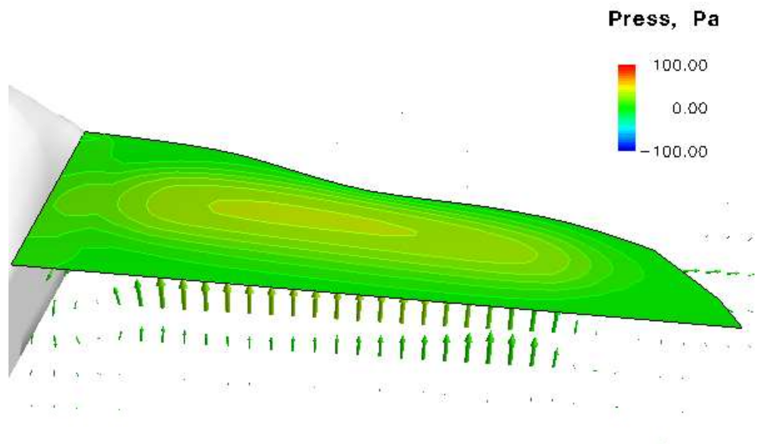
Custom Dev

Development Approach

Membrane FSI

The method utilized modeling the movement of the wing surface due to pressure forces is the Thin Membrane Deformation approach using the successive over-relaxation (SOR) method,

$$T^*(d2u/dx2+d2u/dy2) = -p(x,y)$$



where **T** is the membrane tension force in (kg-m/s^2). At each time-step the pressure and viscous forces exerted on the wing are integrated , and utilized in the FSI algorithm for determining membrane displacement.

TOPICS

Membrane FSI Application

Custom Dev

Project Objectives

Fluid-Structure Interaction (FSI) - Flapping Wing

The primary objective was to establish a baseline simulation capability for flapping wing insects. The capability allows for determining acoustic signatures developed during wing beating for different species of beetles.

Numerical results compared to experimental measurements to be published, and subsequently follow-on funding will be sought (e.g., NSF).